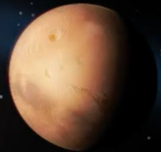# The meteoroid fluence at Mars due to Comet C/2013 A1 (Siding Spring): Two models

Althea Moorhead
NASA Meteoroid Environment Office
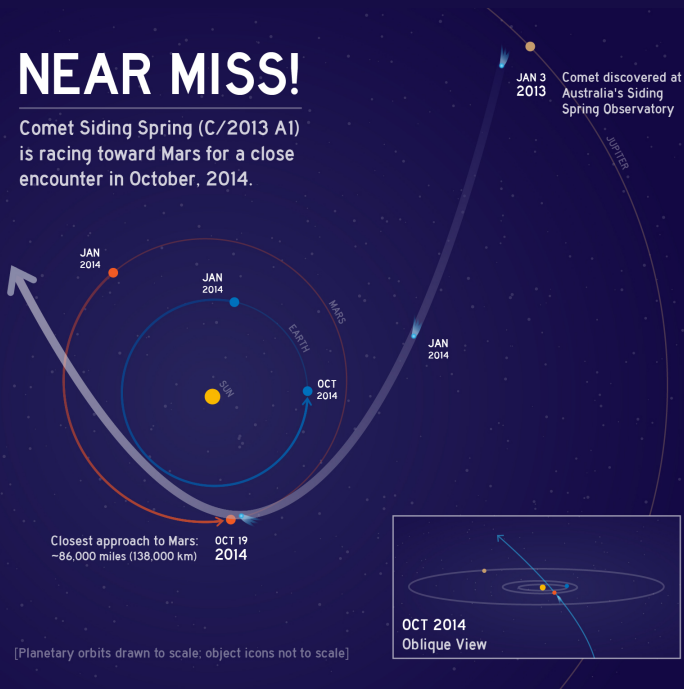
Collaborators:
Paul Wiegert (UWO) & Bill Cooke
Rhiannon Blaauw & Aaron Kingery
Will Yoder & Cameron McCarty

July 2, 2014

NEAR MISS!

Comet Siding Spring (C/2013 A1) is racing toward Mars for a close encounter in October, 2014.

JAN 3 2013 — Comet discovered at Australia's Siding Spring Observatory

JUPITER

JAN 2014

JAN 2014

JAN 2014

MARS

EARTH

SUN

OCT 2014

Closest approach to Mars: ~86,000 miles (138,000 km)

OCT 19 2014

OCT 2014 Oblique View

[Planetary orbits drawn to scale; object icons not to scale]

Image credit: NASA/JPL

Spherical model

Quantifying the number of $\gtrsim 100$ micron[1] particles:

1. Determine brightness.
2. Use particle albedo to compute the total particle surface area.
3. Use particle size distribution, bulk density to compute number of particles.
4. Use r^{-2} spatial distribution to compute the number density.
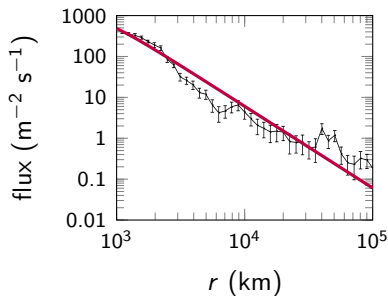5. Integrate along the trajectory to get fluence.

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[1] 100 micron particles are capable of cutting exposed spacecraft wires.

Spherical model
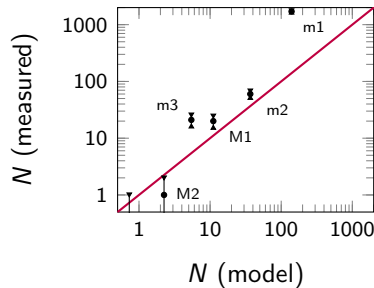
$$\sigma_* = \frac{g h^{-\beta}}{a} \left(\frac{2}{\pi}\right)^{\frac{1}{3}} \left(\frac{\rho}{3}\right)^{\frac{2}{3}} 10^{-0.4(M1 - m_{\odot, 1au})} \text{ au}^2$$
$$\times \left(\frac{3-k}{1-k}\right) \left(\frac{m_{\max}^{(1-k)/3} - m_*^{(1-k)/3}}{m_{\max}^{(3-k)/3} - m_{\min}^{(3-k)/3}}\right)$$
$$\times \frac{\cos^{-1}(b/r_c)}{b \; r_c}$$

This analytic model can be used to quickly calculate new fluence estimates as comet properties are measured/constrained.

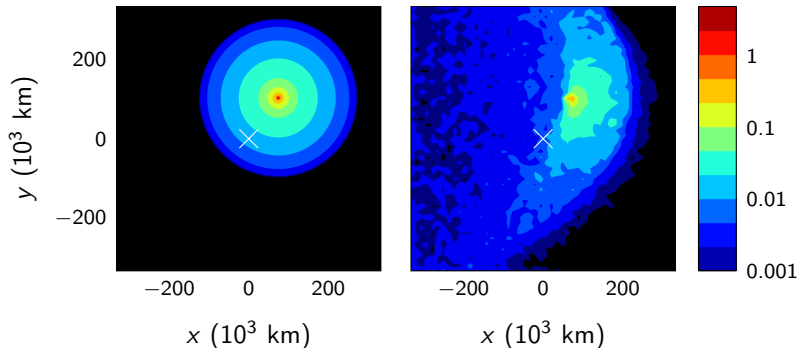# Reproducing *Giotto* and *Stardust* results
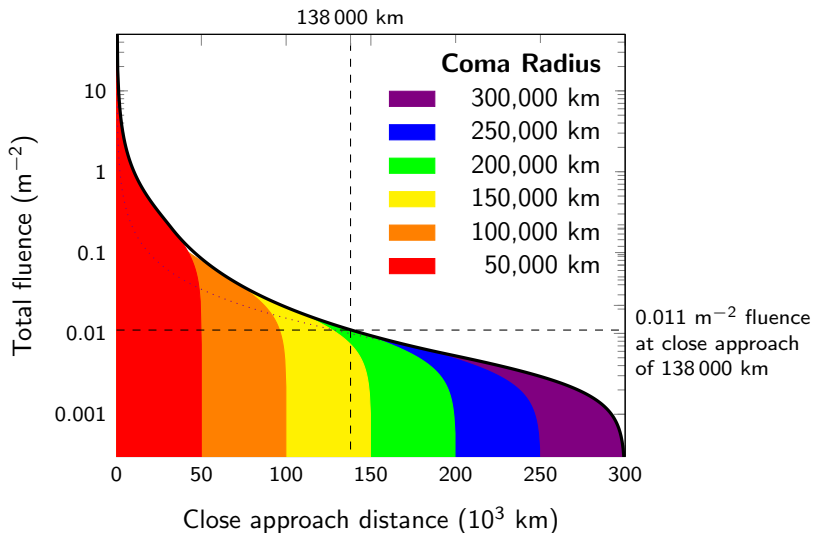

Halley data (Fulle et al., 2000), our model

Wild 2 data (Tuzzolino et al., 2004), our model

Comparison with simulations

Simulations illustrate (modest) deviance from spherical model due to coma asymmetry and tail.

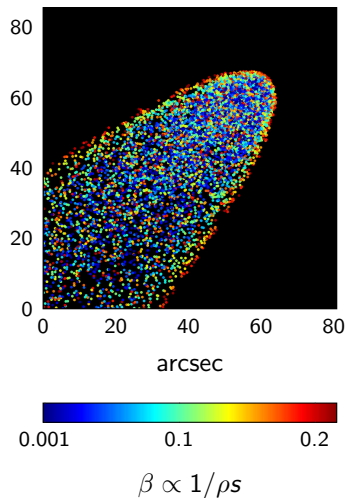# Dependence on coma size

Quasi-Keplerian model

Trajectory:

$$v_{ej} = v_0 \; \beta^{-\mu} r^{-\nu}$$

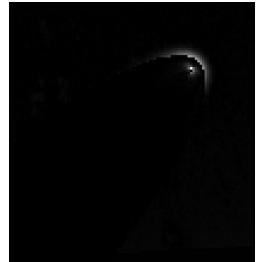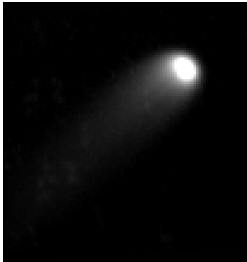$$\vec{F} = -\frac{GMm}{r^2}\left(1 - \beta\right)\hat{r}$$

Particle distribution:

$$\frac{dN}{d\beta} \propto \beta^{\alpha}, \quad \frac{dN}{dr} \propto r^{-\gamma}$$

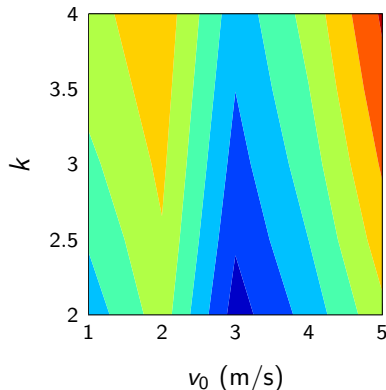$$\frac{dN}{dv} \propto 1 - \left(\frac{v/v_{ej} - 1}{f_v}\right)^2$$

arcsec

$0.001 \qquad 0.1 \qquad 0.2$

$$\beta \propto 1/\rho s$$

Fit to observations

Using efficient algorithms to solve Kepler's equation (Gooding & Odell, 1988), we can simulate 10^6 particles in seconds:

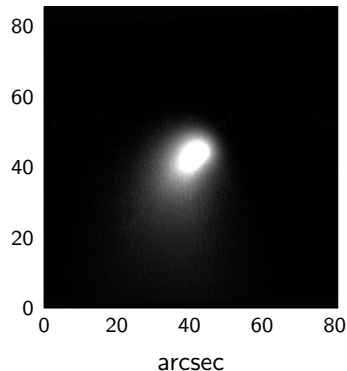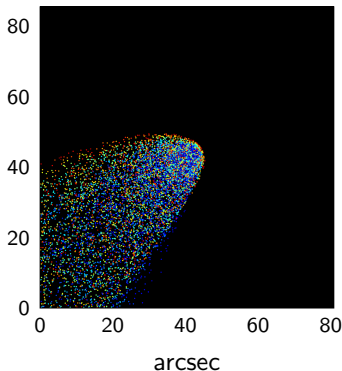We use Hubble images (Li et al., 2014) to fit for six parameters.
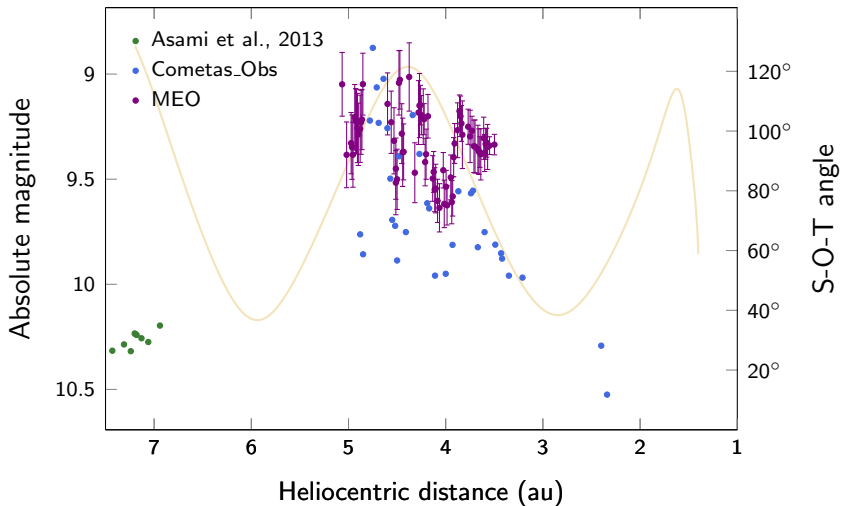
Preliminary results

- Used a coarse, 6-d parameter grid
- Simultaneous fitting of all 3 Hubble observations
- Velocities $\sim$ a few m/s
- Flat-to-inverted size distribution favored

Size distribution

Comet's shape in October images requires large particles/small β

Incorporating additional observations

Summary

We've developed two comet models:

- A spherical, analytic model that describes the particle distribution within the coma
    - Provides rough estimate of the meteoroid environment
    - Recreates Halley and Wild 2 particle counts to within an order of magnitude
    - No longer useful for Siding Spring at Mars
- A fast, quasi-Keplerian model that describes the particle distribution in the coma and tail
    - Can be combined with observations to fit for ejection velocity and particle distribution
    - Preliminary fit favors low velocity, flat/inverted size distribution
    - Future work: incorporate ground observations, apply to other monitored comets